STUDY ON EFFECTIVENESS OF THE DIFFERENT INDUSTRIAL BY-PRODUCTS ON HIGH PERFORMANCE CONCRETE

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Abstract*:* This paper presents the experiments investigation on the effective use of Silica fume, Bottom ash and Steel slag aggregate as a replacement of Cement, Fine aggregate and Coarse aggregate on the properties of High performance concrete. A preliminary study was made to find out the isolated effect and its optimum percentage of Silica fume, Bottom ash and Steel slag aggregate for making High performance concrete. The experimental work includes the workability test as well as mechanical test of High performance concrete. The mechanical properties by applying compressive strength, Young's modulus and flexural strength were investigated. There were a total of 15 mixes prepared with different by-products contents. Out of 14 were High performance concrete mixes and 1 were CC mixes. In this paper we shall discuss the properties of silica fume and its effect on concrete after addition. Bottom ash is a waste material from coal-fired thermal power plants. Unlike its companion–pulverized fuel ash, it usually has no pozzolanic property which makes it unsuitable to be used as a cement replacement material in concrete. However, its particle distribution is similar to that of sand makes it attractive to be used as a sand replacement material. Slag is a by-product of metal smelting and hundreds of tons of it are produced every year all over the world in the process of refining metals and making alloys. Like other industrial byproducts, slag actually has many users and rarely goes to waste. It appears in concrete, aggregate road materials, as ballast, and is sometimes used as a component of phosphate fertilizer. The investigation revealed that the combined use of industrial by products Silica fume, Bottom ash and Steel slag aggregate improved the mechanical properties of High performance concrete and thus there 3 materials may used as a partial replacement material in concrete making.

Keywords - HPC, Silica fume, Bottom ash, and Steel slag aggregate, properties, concrete.

I. INTRODUCTION

Industrial by-products such as silica fume, bottom ash and steel slag aggregate improve the engineering and performance properties of high performance concrete when they are used as a mineral additive or as partial raw material replacement. With the progress of research on by-products in recent years, the use of materials as such as silica fume as binders has been increasing, along with bottom ash. By using these by-products, we can improve cost and environmental effects depending on the characteristics of the by-products. Any concrete which satisfies certain criteria proposed to overcome limitations of conventional concretes may be called High Performance concrete (HPC). It includes concrete which provides either substantially improved resistance to environmental influences or substantially increased structural capacity while maintaining adequate durability. There is no unique definition of high performance concrete but a more broad definition of high performance concrete was adopted by the American Concrete Institute. HPC was defined as concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices. The requirements may involve enhancements of characteristics such as placement and compaction without segregation, long term mechanical properties, early age strength, volume stability, or service life in severe environments. Concretes possessing many of these characteristics often achieve higher strength. Therefore HPC is often of high strength, but high strength concrete may not necessarily be of high performance.

The high performance concrete usually contains both pozzolanic and chemical and mineral admixtures. Hence, the rate of hydration of cement and the rate of strength development in HPC is quite different from that of conventional cement concrete. This HPC can be used where both strength and durability are more important considerations and to produce a more economical product, provide a feasible technical solution, or a combination of both. Now a day a new generation HPC require along with improved compressive strengths, high tensile strength, reduced porosity and very high durability. In HPC, it is necessary to reduce the w/c ratio and which in general increases the cement content. To overcome these low workability problem, different kinds of mineral admixtures of industrial by-products like silica fume, bottom ash and steel slag aggregate can be used. Also at the same time, chemical admixtures such as high range water reducers are needed to achieve the required workability, to ensure that the concrete is easy to transport, place and finish and to ensure that the concrete meets the specified performance [1].

In this study on High performance concrete, a pozzolanic material bottom ash, mineral admixture silica fume and industrial by-product steel slag aggregate can be used. The first recorded testing of

Silica fume in Portland cement based concrete was back in 1952 and till 1970's concretes containing silica fume came into even limited use. Lack of silica fume as an experiment material hindered the investigation of its unique properties [2]. Bottom ash is collected at the end of the grate in a Waste-to-Energy plant. It consists of non-combustible materials, and is the residual part from the incineration of household and similar waste. Raw bottom ash is a granular material that consists of a mix of inert materials such as sand, stone, glass, porcelain, metals, and ash from burnt materials [3]. A steel slag aggregate is a industrial by-product which is obtained from Vedha industry, Karaikal, Puducherry state, a huge quantity of steel slag is produced. These industrial waste storage disposals are becoming a serious environmental problem. Hence there is a need for recycling and use as by-product materials. The present scenario demands identification of substitute materials for raw materials for making high performance concrete. Firstly, slag represents undesired impurities in the metals, which float to the top during the smelting process. Secondly, metals start to oxidize as they are smelted, and slag forms a protective crust of oxides on the top of the metal being smelted, protecting the liquid metal underneath. When the metal is smelted to satisfaction, the slag is skimmed from the top and disposed of in a slag heap to age. Aging material is an important part of the process, as it needs to be exposed to the weather and allowed to bread down slightly before it can be used [4]. In this experiment investigation an attempt is made to study the effect of partial replacement of cement, fine aggregate and coarse aggregate by silica fume, bottom ash, and steel slag aggregate in the mechanical properties of M_{30} grade of concrete.

III. OBJECTIVE

The main objective of this investigation is to determine the suitable percentage of silica fume, bottom ash & steel slag aggregate replaced for cement, fine aggregate & coarse aggregate and influence for different proportioning of super plasticizer in HPC that gives the highest value of concrete mechanical properties.

II. LITERATURE COLLECTION

Kapugamage and Amarasiri (2009) reported that the loss in early strength due to the addition of 15 % fly ash can be completely negated by the addition of 30 % quarry dust. The strength at 28-day age has not been adversely affected at all by the addition of up to 30 % fly ash. The addition of quarry dust causes a loss in slump though such loss in sump can be significantly reduced by the addition of fly ash. Replacement fine aggregate by crusher dust up to 50% by weight has a negligible effect on the reduction of a compressive strength, flexural strength, split tensile strength etc. Water absorption is well below the limit as per Indian codes. Durability test shows no variation for different replacements of quarry dust. Krishnamoorthi and Kumar (2010) reported that The 3 and 7 days cube compressive strength for concrete with 20% and 40% quarry dust is same as conventional concrete and with above 40% quarry dust the strength decreases subsequently. 28 days strength satisfies the target strength. The split tensile strength and flexural strength of concrete made with 40% of replacement of sand with quarry dust is more than that made with other percentage of replacement. The compressive strength of concrete made with 40% of quarry dust is more than that made with 0%, 20%, 50%, and 60% of quarry dust. Tensile strength of concrete made with 40% of quarry dust is more than that made with 0%, 20%, 50%, and 60% of quarry dust. Tensile strength of concrete made with 60% of quarry dust is more than that made with 0% of quarry dust. Reddy et al (2007) reported that the compressive strength of concrete was increased with increase of age of concrete with partial replacement of fine aggregate by quarry dust. Compare to the control specimen the corresponding increase in 56 days compressive strength of specimens with 10 and 40% of partial replacement of fine aggregate by quarry dust was 11% to 5% respectively. Nadgir and bhavikatti (2008), The experimental result show that the split tensile strength increases up to 40% stone quarry dust beyond which reduces They have contended that partially replacement of sand by stone quarry dust ,will not affect the strength.

IV. EXPERIMENTAL INVESTIGATION

In this investigation, 45-cubes, 45-cylinders, 45-prisms were tested to investigate concrete compressive strength, Young's modulus and flexural strength of HPC with the combination of silica fume, bottom ash and steel slag aggregate of different proportions. All test specimens of cube with 150mm X 150mm size and cylinders with diameter of 150mm and 300mm in length, 100mm X 100mm X 500mm of prism. In the experimental study, generally a good quality of cement like 43 grade cement is preferred but it may vary according to the grade of HPC needed. Natural sands crushed and rounded sands and manufactured sands are suitable for HPC. River sand of specific gravity 2.61 and conforming to zone II of IS 363 was used for the present study. The shape and particle size distribution of the aggregate is very important as it affects the packing and voids content. The moisture content, water absorption, grading and variations in fines content of all aggregate should be closely and continuously monitored and must be taken into account in order to produce HPC of constant quality. Coarse aggregate used in this study had a maximum size of 10mm. Specific gravity of coarse aggregate used was 2.66 as per IS 363. Ordinary potable water was used. Silica fume shall confirm to the ASTM C 1240 specification as shown in Table No. 1. Silica Fume used was Elkem Micro Silica Grade 920-D

(Non Combustible Amorphous S_i0_2 – Densified) in dry state and packed in 20 kg bags, obtained from thermal power plant, Neyveli Lignite Corporation Ltd., Neyveli, Tamil Nadu, India was used in this investigation. The Specific Gravity and Fineness modulus of Bottom ash was 2.36 and 2.39. The chemical composition of slag is usually expressed in terms of simple oxides calculated from electrical analysis determined by X-ray fluorescence.

V. MIX PROPORTION

A development of 15 mix of HPC based on by-product amount, the experiment program was designed to study the mechanical properties of concrete with partial replacement of cement by silica fume, fine aggregate by bottom ash, coarse aggregate by steel slag aggregate for M_{30} grade of concrete. The compressive, split tensile and flexural strength of the specimens after replacing the cement by 5%, 10%, 15%, 20% with silica fume and fine aggregate, coarse aggregate by 10%, 20%, 30%, 40%, and 50% with Bottom ash and steel slag aggregate is studied after 28 days of curing. For the test specimens, 43 grade OPC, Natural river sand, coarse aggregate, silica fume, bottom ash, steel slag aggregate from power plants is being utilized. The concrete mix design was proposed to achieve the compressive strength of 30 MPa after 28 days curing in case of cubes. The concrete mix proportions used, have been determined as per IS method of mix design. The methodology of the experiment was tested the fresh properties and then hardened properties such as compressive strength, splitting tensile and flexural strength which can be conducted if the freshness requirements was achieved as requirements. The HPC mixes were prepared using hand mixing and drum mixer, the mixer was firstly washed with water to ensure that there is no absorption inside and secondly the both aggregate were mixed with the half of water and left it for 2 minutes to let the water completely absorbed with aggregate, then thirdly the cement and mineral admixture (if needed) is added with mix of remaining water and super plasticizer for 4 minutes to allow the reaction of chemical admixture to completed, and finally the mixer left for 4 minutes to allow the ingredients to distribute uniformly inside the concrete mixer. Each sample was tested to determine the density and compressive strength at various stages after undergoing water curing. After demolding, the specimens were transferred to the water tank for further curing until the age of the test. The specimens have been on the saturated surface dry condition. The compressive strength of the cube immediately tested after obtaining their densities. The splitting tensile and flexural strength tests were conducted by using the cylinders and prism respectively. The axial compressive load was applied to $100mm^3$ cube samples by using a universal testing machine (UTM) with a capacity of 1000 KN.

MIX PROPORTIONS OF SILICA FUME kg/m^3				
Materials	Concrete with Silica Fume			
	Cement replacement levels			
	SFC 5%	SFC 10%	SFC 15%	SFC 20%
Cement	363.85	344.70	325.55	306.40
Silica Fume	19.15	38.30	57.45	76.60
Sand	655	655	655	655
CA	1200	1200	1200	1200
Water	172.4	172.4	172.4	172.4

Table 1, Mix Proportions of Silica fume

MIX PROPORTIONS OF BOTTOM ASH kg/m^3					
Materials	Concrete with Bottom Ash				
	Fine aggregate replacement levels				
	BAC 10%	BAC 20%	BAC 30%	BAC 40%	BAC 50%
Cement	383	383	383	383	383
Sand	589.5	524	458.5	393	327.5
Bottom ash	65.5	131	196.5	262	327.5
CA	1200	1200	1200	1200	1200
Water	172.4	172.4	172.4	172.4	172.4

Table 2, Mix Proportions of Bottom ash

MIX PROPORTIONS OF STEEL SLAG AGGREGATE kg/m^3					
Materials	Concrete with steel slag aggregate				
	Coarse aggregate replacement levels				
	SSAC 10%	SSAC 20%	SSAC 30%	SSAC 40%	SSAC 50%
Cement	383	383	383	383	383
Sand	655	655	655	655	655
CA	1080	960	840	720	600
SSA	120	240	360	480	600
Water	172.4	172.4	172.4	172.4	172.4

Table 3, Mix Proportions of Steel slag aggregate

VI. MATERIAL SELECTION

The cement used for the investigation was 43 grade ordinary Portland cement (OPC). The initial and final setting times were 45 and 300 minutes respectively. The fine aggregate used in the experiment were clean natural sand with specific gravity of 2.61 and fineness modulus of 2.76. While coarse aggregate was used as (10-5) mm crushed granite stone with specific gravity of 2.66. Silica Fume used was Elkem Micro Silica Grade 920-D (Non Combustible Amorphous S_i0_2 – Densified) in dry state and packed

in 20 kg bags, obtained from thermal power plant, Neyveli Lignite Corporation Ltd., Neyveli, Tamil Nadu, India was used in this investigation. The Specific Gravity and Fineness modulus of Bottom ash was 2.36 and 2.85. Table 4 lists the range of compounds present in Industrial by-products.

Constituent	Silica Fume	Bottom Ash	Steel slag
$Si0_2$	92	28.4	29.3
Al_20_3	0.7	8.54	3.16
Fe_20_3	1.2	1.51	26.48
Ca0	0.3	50	33.2
M_g0	0.2	4.72	6.4
$S0_3$	0.3	3.44	0.71
K_20	1.8	0.74	0.04
Na_20	1.5	0.22	0.09

Table 4, Chemical composition of materials

VII. CASTING & EXPERIMENTAL PROCEDURE

The methodology of the experiment was tested the fresh properties and then hardened properties such as compressive strength, splitting tensile and flexural strength which can be conducted if the freshness requirements was achieved as requirements. The HPC mixes were prepared using hand mixing and drum mixer, the mixer was firstly washed with water to ensure that there is no absorption inside and secondly the both aggregate were mixed with the half of water and left it for 2 minutes to let the water completely absorbed with aggregate, then thirdly the cement and mineral admixture (if needed) is added with mix of remaining water and super plasticizer for 4 minutes to allow the reaction of chemical admixture to completed, and finally the mixer left for 4 minutes to allow the ingredients to distribute uniformly inside the concrete mixer. Each sample was tested to determine the density and compressive strength at various stages after undergoing water curing.

After demoulding, the specimens were transferred to the water tank for further curing until the age of the test. The specimens have been on the saturated surface dry condition. The compressive strength of the cube immediately tested after obtaining their densities. The splitting tensile and flexural strength tests were conducted by using the cylinders and prism respectively. The axial compressive load was applied to cube samples by using a universal testing machine (UTM) with a capacity of 1000 KN.

A. Fresh Properties

The outcomes of fresh test as slump cone test for HPC mixes are provided. In relation to slump flow, all HPC mixes showed acceptable slump flows of the good deformability. The 5% of silica fume, 10% of bottom ash, 10% of steel slag aggregate have proven greater than CC and other percentages which demonstrate lower slump flow values. Attributable to its spherical shape, silica fume contaminants had a spherical geometry and coarse particle size leading to decrease the surface area. A partial replacement of cement by silica fume and fine aggregate by bottom ash reductions down on the friction in the fine aggregate-paste interface and enhances the cohesiveness, and also resulted in increased workability.

SL.NO	CODE MIX	Compressive strength MPa	Split tensile strength MPa	Flexural strength MPa
1	CC	34.795	2.77	7.11
2	SFC1	36.42	3.64	9.05
3	SFC2	34.15	3.35	8.62
4	SFC3	32.48	3.01	7.11
5	SFC4	31.95	2.89	6.68

SL.NO	CODE MIX	Compressive strength MPa	Split tensile strength MPa	Flexural strength MPa
1	BAC1	35.32	3.80	8.94
2	BAC2	33.66	3.53	8.05
3	BAC3	32.15	3.37	6.46
4	BAC4	31.04	2.39	6.03
5	BAC5	29.41	2.38	5.82

SL.NO	CODE MIX	Compressive strength MPa	Split tensile strength MPa	Flexural strength MPa
1	SSAC1	39.55	3.88	8.67
2	SSAC2	36.55	3.61	8.48
3	SSAC3	35.86	3.28	7.11
4	SSAC4	32.95	2.33	6.90
5	SSAC5	31.39	2.21	6.25

Table 5, Mechanical Properties test results of Silica fume
Table 6, Mechanical Properties test results of Bottom ash
Table 7, Mechanical Properties test results of Steel slag aggregate

B. Compressive strength result

Compressive strength test had been conducted for 28 days strength three cubes were cast for each one and the average was calculated. The results are tabulated in Table. It shows the relative effect of by-products on the compressive strength of the HPC mixes. The results were compared with the results of conventional concrete specimens. HPC has higher compressive strength than the conventional concrete with increasing percentage varies from 5% to 10% for 0.42 water-cement ratios. When by-products are

added as additional admixtures there is a significant improvement in the strength of concrete. The 5% of Silica fume increases the compressive strength compared with 10%, 15% & 20% ratios. The 10% of Bottom ash and steel slag aggregate increases the compressive strength compared with 20%, 30%, 40% and 50% ratios respectively after 28 days of curing. Regarding to the HPC mixes the 10% of steel slag aggregate gain high compressive strength than other percentages of HPC mixes.

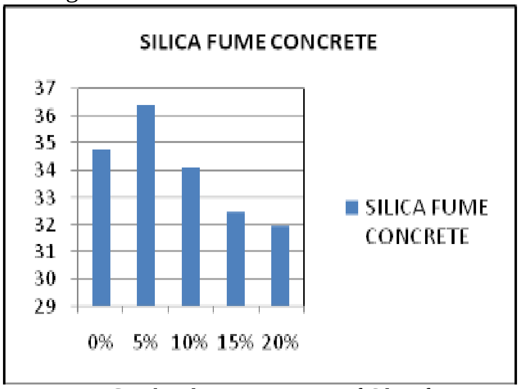

Fig 1: Graphical representation of Silica fume

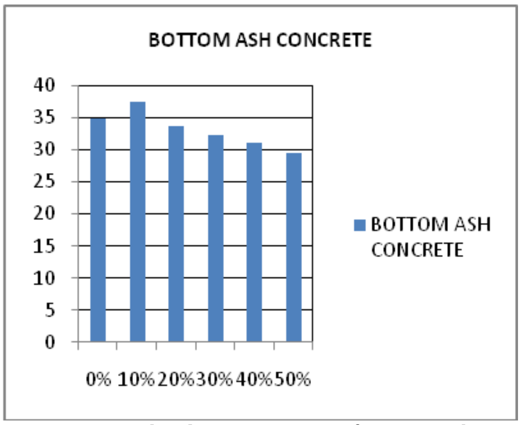

Fig 2: Graphical representation of Bottom ash

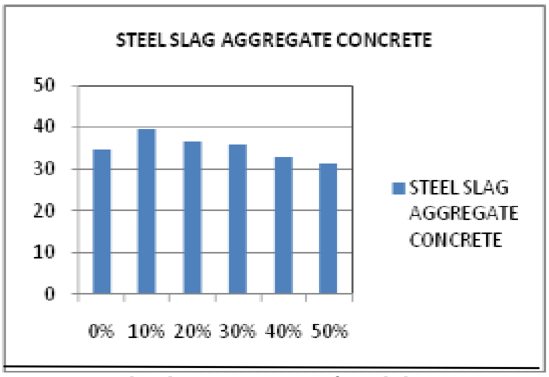

Fig 3: Graphical representation of Steel slag aggregate

C. Splitting tensile strength

Concrete cylinder specimens of diameter 100mm and 200mm length were cast for testing in the age of 28 days. Table shows the result of splitting tensile strength of 28 days per each mix. The Split tensile strength of HPC varies from 2.70 to 3.88 MPa. When compared to conventional concrete strength it is observed that increase in strength varies for 0.42 water cement ratio.

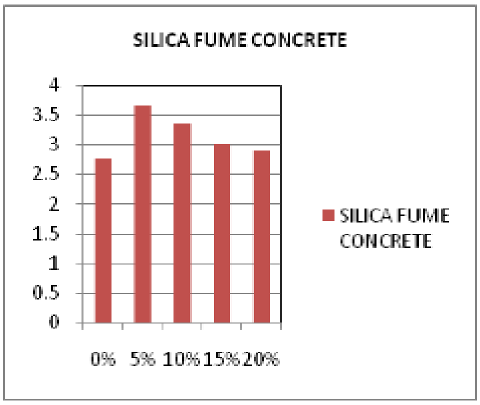

Fig 4: Graphical representation of Silica fume

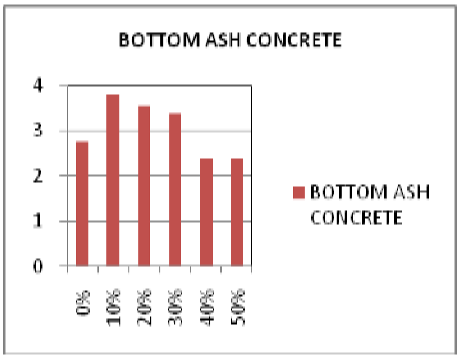

Fig 5: Graphical representation of Bottom ash

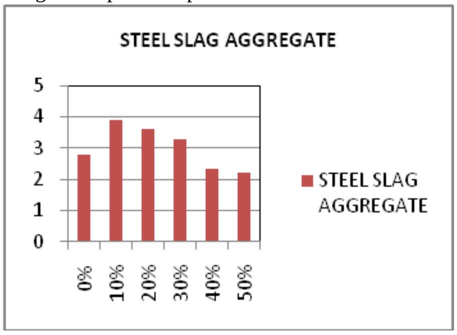

Fig 6: Graphical representation of Steel slag aggregate

D. Flexural Strength test result

Flexural strength of HPC mixes was determined at 28 days. The results were compared with the results of conventional concrete specimens which are tabulated in Table 9. The split tensile strength varies from 5.82 to 9.05 MPa. When compared to conventional concrete strength it is observed that increase in strength varies for 0.42 water cement ratio.

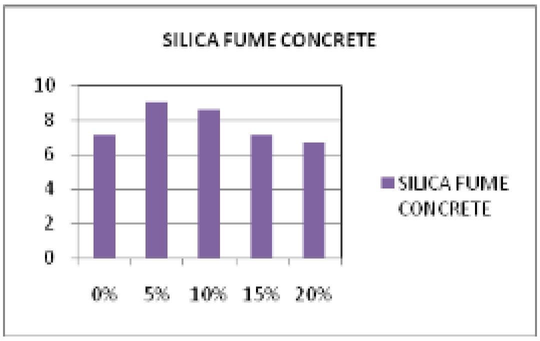

Fig 7: Graphical representation of Silica fume

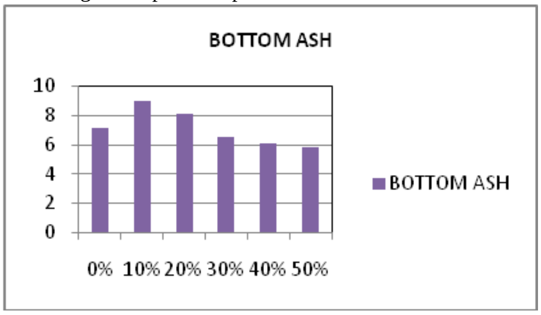

Fig 8: Graphical representation of Bottom ash

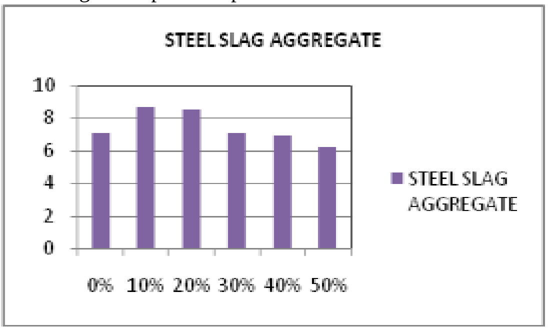

Fig 9: Graphical representation of Steel slag aggregate

VIII. ANALYTICAL RESULT

An artificial neural network is an artificial intelligence technique. It is a simulation of human brain- like architecture. An artificial neural network is a massively distributed processor made up of interconnection of simple processing elements i.e. neurons outputs are connected, through weights, to all other neurons including themselves, It resembles brain in mainly in the aspects of. The factors that determine, the behaviour of a given neural network are weights of the connections. In a large network the contribution of a single weight is often slight; it is the effect of combination of connection weights that determines the output. The process of training a network is that of finding a set of values for the weights that make the network do what you want it to do. Mathematicians are still working on this, but is appears that given enough hidden units and connections there is little that a net is unable to do.

Then the problem is in finding the right box to train generalized regression neural networks to solve specific problems. There is no way to determine a good network topology just from the number of inputs and outputs. It depends critically on the number of training examples and the complexity of the classification is trying to learn. There are problems with one input and one output that require only one hidden unit or none at all. In most situations, there is no way to determine the best number of hidden units without training several networks and estimating the generalization error of each if you have too few hidden units, you will get high training error and high statistical bias, if you have too many hidden units, you may get low training error but still have high generalization error due to over fitting and high variance.

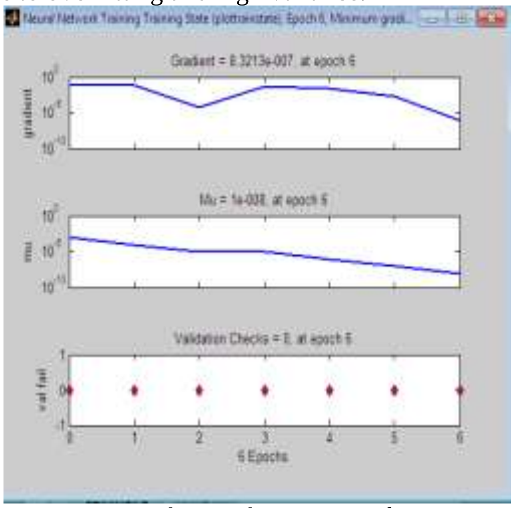

Fig 11, Neural Network Training Performance

IX. CONCLUSIONS AND DISCUSSIONS

The detailed experimental work conducted in this study and analysis revealed the following conclusion:

a) Silica fume, bottom ash and steel slag aggregate can be transformed into useful raw materials in concrete making.
b) Even partial replacements in volume of cement, sand and coarse aggregate with silica fume, bottom ash, and coarse aggregate respectively in concrete mixes would lead to considerable savings in consumption of cement and sand and enables the large utilization of waste product.
c) 5% of silica fume, 10% of bottom ash and 10% of steel slag aggregate mixes showed highest compressive strength as compared to the control mix. Whereas all by-product mixes resulted in high flexural strength, which was due to the negligible bleeding and high cohesiveness.
d) The results of mechanical properties are represented in graph. The test results shows that the compressive strength of the concrete and the optimum value was found at a Silica fume replacement proportions of 5% for cement and Bottom ash & Steel slag aggregate replacement proportion of 10% for fine & coarse aggregate and after that any further replacement of silica fume, bottom ash and steel slag aggregate decreases the compressive strength.
e) The tensile and flexural strength values follow the same for all the replacement proportions.
f) This work relates the use of Industrial by-products; a waste cheap material used as a raw

material in M30 grade of concrete and recommends the approval of materials for use in concrete as replacement materials for cement, fine and coarse aggregate.

The partial substitution of fine and coarse aggregate with Bottom ash and Steel slag aggregate permits a gain of compressive, tensile and flexural strength of concrete upto an optimum value of replacement.

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